Lessons Learned and Advances in Human Factors and Safety Culture in Process Safety Management (PSM) in the Energy Industry:

From Up- to Downstream

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Prevention First 2018 Symposium
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Long Beach, California

My story…

Last 30 years of working directly with and experience with:

- **Nuclear power**
- **Petrochemical**
- **Refining**
- **Oil & Gas Pipeline**
- **Offshore Drilling**
- **Aviation**
- **Railroad**
- **Maritime**
- **Coal Mining**

And most recently (last 15+ years) with **Health Care** industries

From Up- to Downstream…

Drilling

BP Deepwater Horizon

Refinery

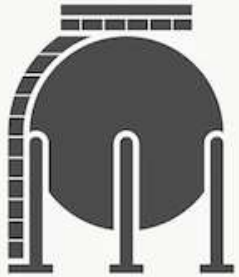
BP Texas City

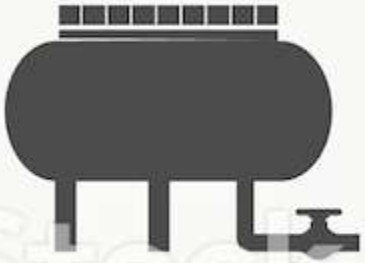
Pipeline*

PG&E San Bruno

Storage

Aliso Canyon

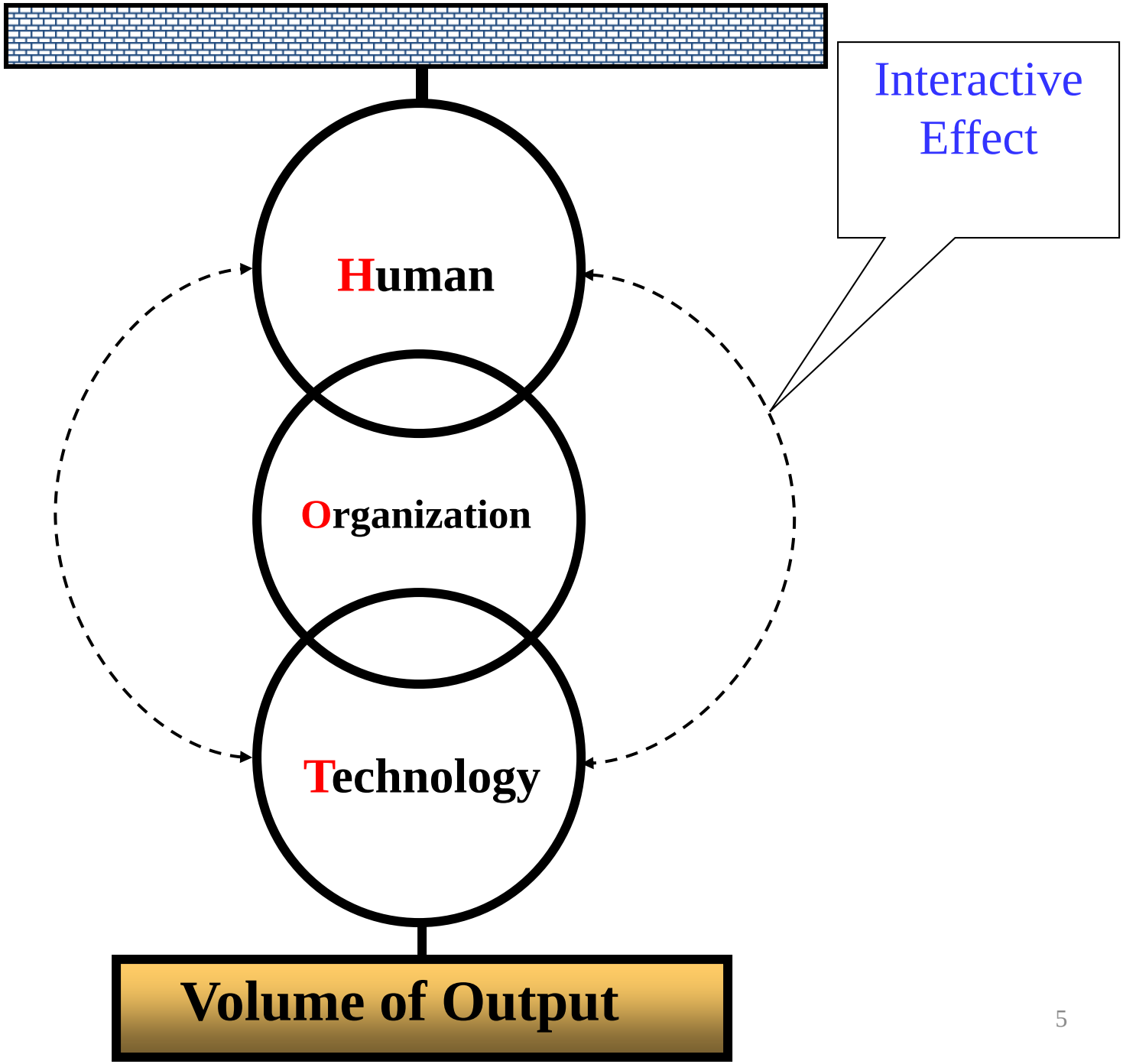


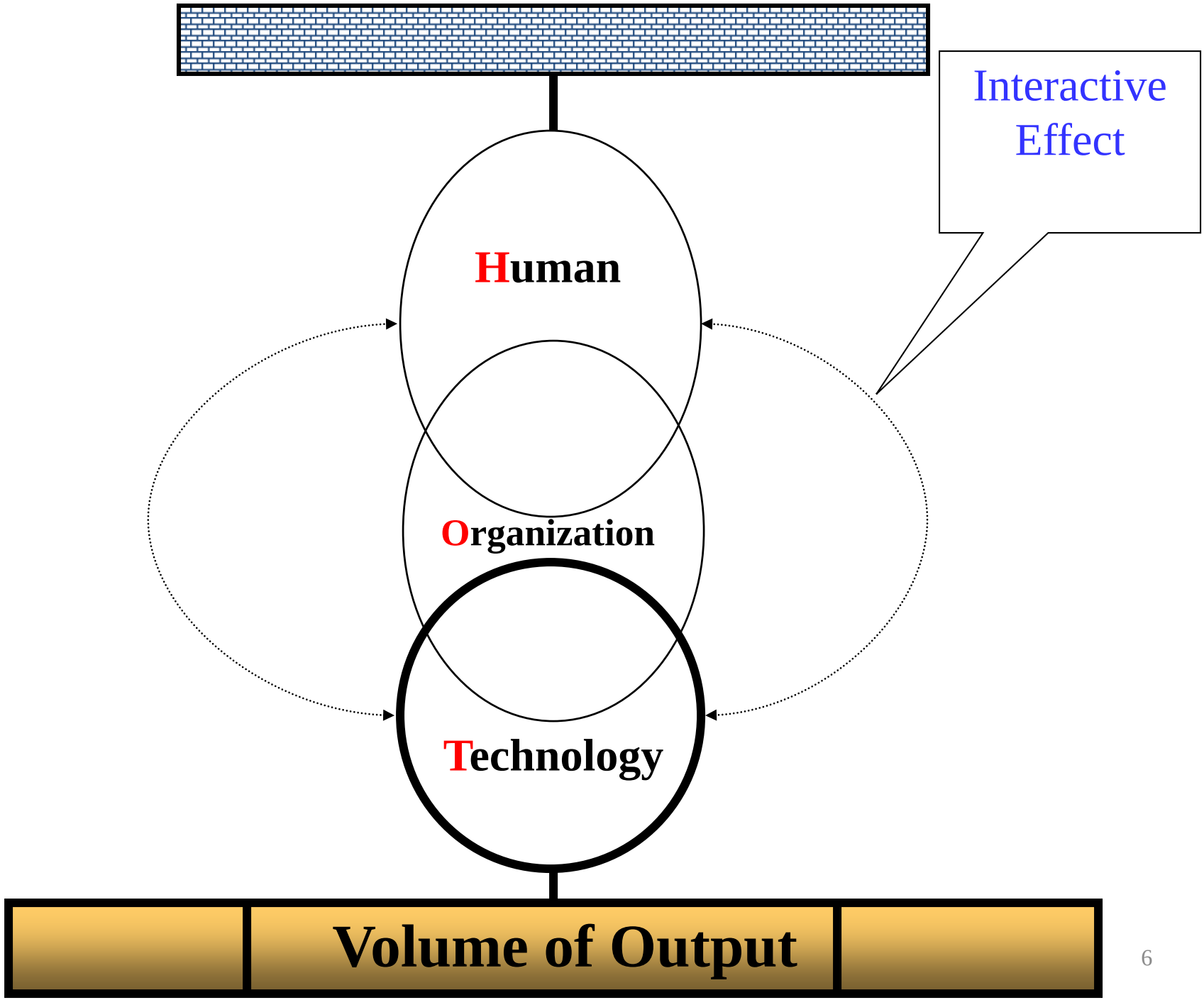


My Premise:

The ‘HOT’ Model
Major Subsystems of a Complex, Large-scale Technological System

(e.g., an offshore drilling/production platform, refinery, oil/gas pipeline system, a gas underground storage facility)

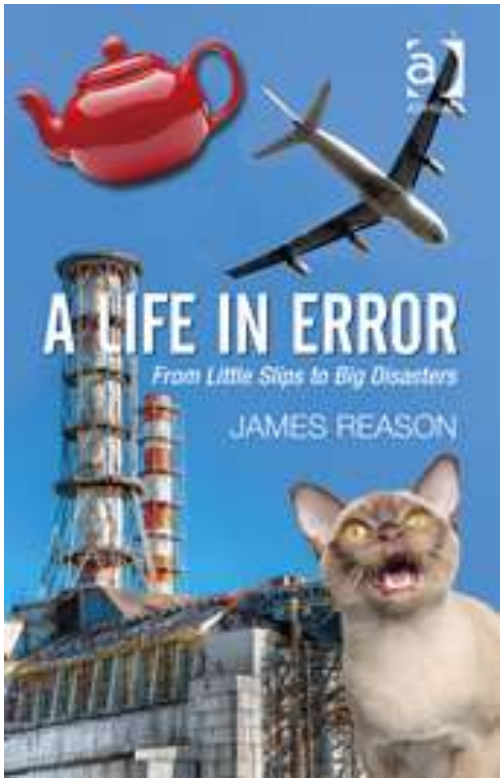

Interactive Effect
Human
Organization
Technology
Volume of Output


Interactive Effect
Human
Organization
Technology
Volume of Output

My Premise:

Safety Culture as a Root-Cause of a System's Common Mode Failure

- Because of their diversity and redundancies, the defense-in-depth will be widely distributed throughout the system.
- As such, they are only collectively vulnerable to something that is equally widespread. The most likely candidate is safety culture.
- It can affect all elements in a system for good or ill.



Professor James Reason, *A Life in Error*, 2013, Page 81

BP Deepwater Horizon Accident

April 20, 2010

BP Deepwater Horizon

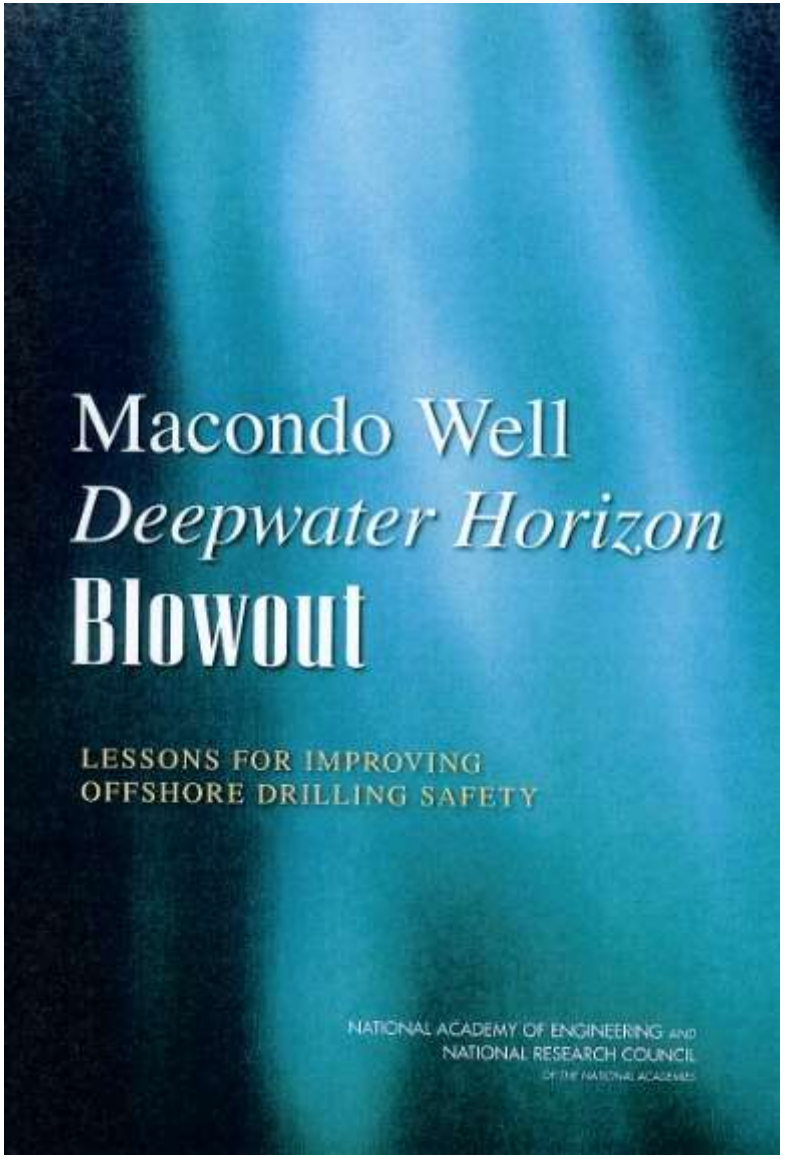
BP Deepwater Horizon

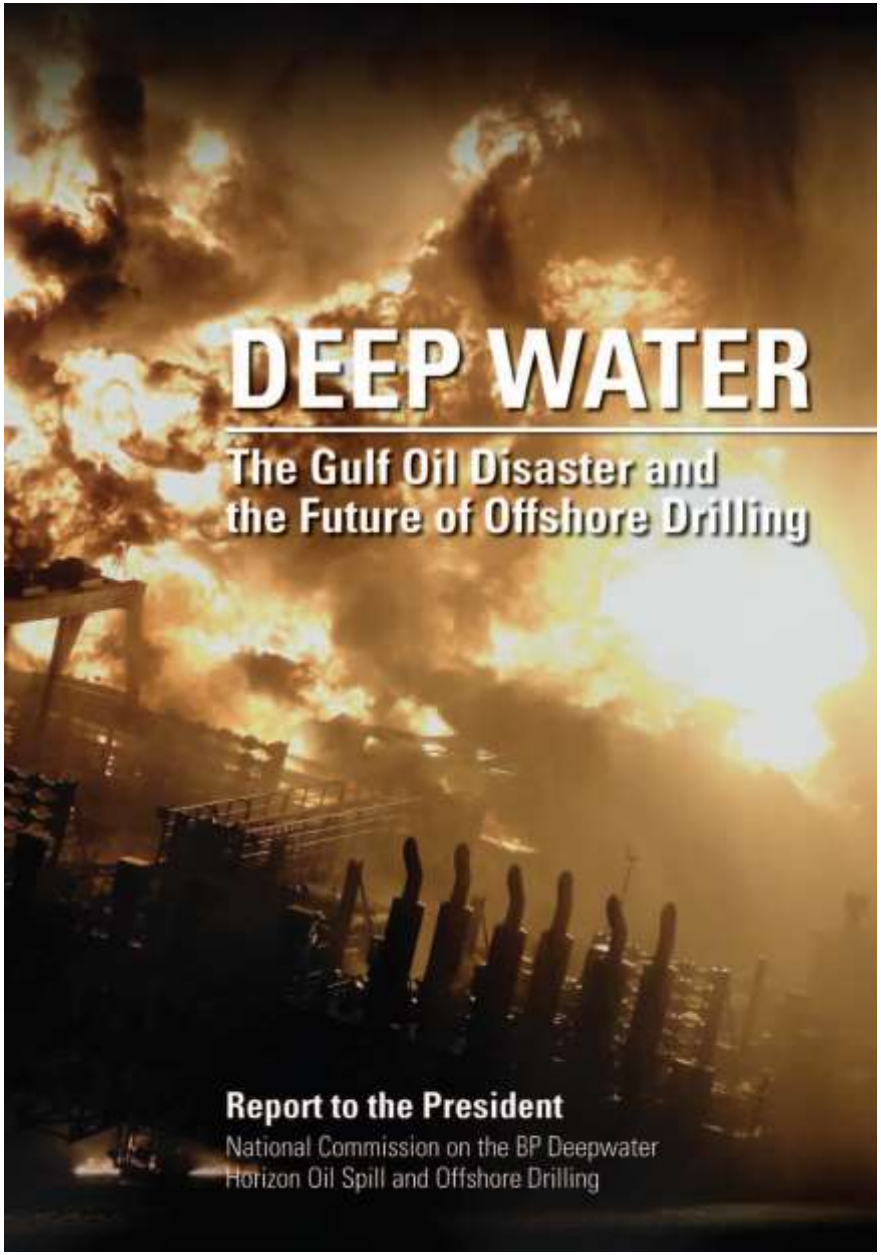
BP Deepwater Horizon Accident

April 20, 2010

11 workers lost their lives and 16 others were seriously injured.

The flow continued for nearly 3 months before the well could be completely killed, during which time, nearly 5 million barrels of oil spilled into the gulf.


Macondo Well
Deepwater Horizon
Blowout
LESSONS FOR IMPROVING
OFFSHORE DRILLING SAFETY
NATIONAL ACADEMY OF ENGINEERING AND
NATIONAL RESEARCH COUNCIL



www.oilspillcommission.gov

Chapter Eight

"Safety is not proprietary."

Changing Business as Usual

The Deepwater Horizon blowout, explosion, and oil spill did not have to happen. Previous chapters have explained the immediate and root causes for why they nonetheless did. The American public, government, and the oil and gas industry need to understand what went wrong so they can pursue the changes required to prevent such devastating accidents from recurring.

This chapter examines how petroleum companies have been managing the risks associated with finding and producing oil and how they can do it better, individually and as a responsible industry overall. The record shows that without effective government oversight, the offshore oil and gas industry will not adequately reduce the risk of accidents, nor prepare effectively to respond in emergencies. However, government oversight, alone, cannot reduce those risks to the full extent possible. Government oversight (see Chapter 9) must be accompanied by the oil and gas industry's internal reinvention: sweeping reforms that accomplish no less than a fundamental transformation of its safety culture. Only through such a demonstrated transformation will industry—in the aftermath of the *Deepwater Horizon* disaster—truly earn the privilege of access to the nation's energy resources located on federal properties.

Even as Deepwater Horizon burns, oil from the blown out well begins to spread across the Gulf. Preventing such disasters in the future will take more effective government oversight. Most crucial, however, will be the oil and gas industry's commitment to fundamentally transform its own safety culture.

< *Gerald Herbert/Associated Press*

"The record shows that without effective government oversight, the offshore oil and gas industry will not adequately reduce the risk of accidents, nor prepare effectively to respond in emergencies. However, government oversight, alone, cannot reduce those risks to the full extent possible. Government oversight (see Chapter 9) must be accompanied by the oil and gas industry's internal reinvention: sweeping reforms that accomplish no less than a fundamental transformation of its **safety culture**"

(p. 217, emphasis added)

Explosion at BP's Texas City Refinery

BP is no stranger to serious accidents. In March 2005, an explosion rocked the company's Texas City refinery near Houston: 15 workers lost their lives. One year later a BP pipeline on Alaska's North Slope ruptured, spilling more than 200,000 gallons of oil onto the fragile tundra. Yet, the report notes, in recent years the company's safety record in the Gulf of Mexico has been excellent.

William Philpott/AFP/Getty Images

resulted in "a number of serious releases," but had ultimately declined to do so "[f]or a variety of reasons—including cost pressures" and BP's ability to take advantage of "the existence of an exemption under [U.S. Environmental Protection Agency] air regulations. . . ."[14]

The Safety Board's report on Texas City noted that "while most attention was focused on the injury rate, the overall safety culture and process safety management program had serious deficiencies. Despite numerous previous fatalities at the Texas City refinery (28 deaths in the 30 years prior to the 2005 disaster) and many hazardous material releases, BP did not take effective steps to stem the growing risks of a catastrophic event."[15] The report added: "Cost-cutting and failure to invest in the 1990s by Amoco (who merged with BP in 1998) and then BP left the Texas City refinery vulnerable to a catastrophe. BP targeted budget cuts of 25 percent in 1999 and another 25 percent in 2005, even though much of the refinery's infrastructure and process equipment were in disrepair. Also, operator training and staffing were downsized."[16]

The Safety Board further singled what it characterized as the "organizational causes embedded in the refinery's culture," including:

- "BP Texas City lacked a reporting and learning culture. Reporting bad news was not encouraged, and often Texas City managers did not effectively investigate incidents or take appropriate corrective action.
- "BP Group lacked focus on controlling major hazard risk. BP management paid attention to, measured, and rewarded personal safety rather than process safety.
- "BP Group and Texas City managers provided ineffective leadership and oversight. BP management did not implement adequate safety oversight, provide needed human and economic resources, or consistently model adherence to safety rules and procedures.
- "BP Group and Texas City did not effectively evaluate the safety implications of major organizational, personnel, and policy changes."[17]

At the Chemical Safety Board's instigation, BP established its own independent panel to review its safety procedures and find ways to improve them.[18] That panel, chaired by former U.S. Secretary of State James Baker III, issued its report a few months before the Chemical Board report in 2007. The Baker panel was no more charitable in its assessment. The panel found that BP management had not distinguished between occupational safety—concern over slips, sprains, and other workplace accidents—and process safety: hazard analysis, design for safety, material verification, equipment maintenance, and process-change reporting. And the panel further concluded that BP was not investing leadership and other resources in managing the highest risks.[19]

The Baker panel especially faulted BP for failing to learn the lessons of Grangemouth by repeating them in the events leading up to the Texas City refinery explosion. According to the panel, "in its response to Grangemouth, BP missed an opportunity to make and sustain company-wide changes that would have resulted in safer workplaces for its employees and contractors."[20] Underscoring the depth of the organizational problem facing BP the panel

singled out for criticism BP's overall approach to accident analysis: "BP's investigation system has not instituted effective root cause analysis procedures to identify systemic causal factors."[21]

Prudhoe Bay pipeline leak. In March 2006—one year after the Texas City refinery explosion and one year before the Chemical Safety Board report on it—BP had yet another significant industrial accident. Its network of pipelines in Prudhoe Bay, Alaska, leaked 212,232 gallons of oil into the delicate tundra environment—the worst spill ever recorded on the North Slope.[22] The leak went undetected for as long as five days.[23] Upon analysis, the pipes were found to have been poorly maintained and inspected.[24] BP paid more than $20 million in fines and restitution.[25]

Progress in follow-up on the safety recommendations. The Baker panel report contained 10 recommendations "intended to promote significant, sustained improvements in BP's process safety performance."[26] Recommendation nine advocated that BP establish an independent expert to monitor and report on its progress in executing the panel's other recommendations in its U.S. refineries, in refining management, and at the BP board and executive management levels.[27] In the executive summary of the third annual report of that expert, covering January–December 2009, he remarked that:

> Delivery against milestones related to implementation of the Recommendations remains a critical performance objective for the U.S. refineries. Virtually all of the milestones in the U.S. Refining's 2009 plans were delivered on schedule.
>
> "While significant gaps have been closed and most of the new systems, processes, standards, and practices required for continued process safety improvements have been developed, much work remains to be done to fully implement them. BP must now demonstrate improved capability for systematic management of these systems, processes, standards, and practices so it can accelerate the overall pace of implementing the Recommendations.[28]

The independent expert also noted, apropos of the Baker panel report's final recommendation that BP use the lessons learned from the Texas City tragedy to transform the company into a recognized industry leader in process safety management:

> BP is striving to transform the company into a recognized industry leader in process safety . . . and . . . has made significant improvements each year in response to all Recommendations. However, much work remains to fully implement the Recommendations. . . . BP will be an industry leader when its process safety performance is superior to that of its peers, and its peers recognize BP as a true leader to emulate.[29]

In recent years in the Gulf of Mexico, BP's safety offshore drilling record was reportedly excellent.[30]

Deepwater Horizon

BP's safety culture failed on the night of April 20, 2010, as reflected in the actions of BP personnel on- and offshore and in the actions of BP's contractors. As described in Chapter 4, BP, Halliburton, and Transocean did not adequately identify or address risks of an accident—not in the well design, cementing, or temporary abandonment procedures. Their management systems were marked by poor communications among BP, Transocean, and Halliburton employees regarding the risks associated with decisions being made. The decisionmaking process on the rig was excessively compartmentalized, so individuals on the rig frequently made critical decisions without fully appreciating just how essential the decisions were to well safety—singly and in combination. As a result, officials made a series of decisions that saved BP, Halliburton, and Transocean time and money—but without full appreciation of the associated risks.

BP conducted its own accident investigation of *Deepwater Horizon*, but once again kept its scope extremely narrow.[31] Professor Najmedin Meshkati of the University of Southern California, Los Angles—a member of the separate National Academy of Engineering committee investigating the oil spill—criticized BP's accident report for neglecting to "address human performance issues and organizational factors which, in any major accident investigation, constitute major contributing factors." He added that BP's investigation also ignored factors such as fatigue, long shifts, and the company's poor safety culture.[32]

Upon reading the BP report, this Commission's Chief Scientific and Engineering Advisor, Richard Sears, commented that "it appeared that for BP, the accident happened at 9:40 p.m. on April 20; whereas in some ways, the blowout began in early 2009 when they initially designed the well."[33]

The Culture on the Rig

BP was operator of the Macondo well and in that capacity had both the overall responsibility for everything that went on and was in the best position to promote a culture of safety on the rig, including in the actions of its two significant contractors, Halliburton and Transocean. But the extensive involvement of those contractors in the mistakes that caused the Macondo well blowout underscores the compelling need for a fundamental shift in industry culture that extends beyond BP. As described in Chapter 2, offshore drilling and energy production involve a complex interrelationship among companies. No single company—not even at the major integrated oil companies—performs the full panoply of activities required for oil and gas drilling. All contract out for the services of other companies for critical aspects of their operations. For this same reason, whatever the specific contractual relationships, operating safely in this environment clearly demands a safety culture that encompasses every element of the extended drilling services, and operating industry.

Transocean, for instance, was a major contractor for the Macondo well and is the world's largest operator of offshore oil rigs, including the *Deepwater Horizon*; Transocean personnel made up the largest single contingent on the rig at the time of the accident, and 9 of the 11 men who died on April 20 worked for the company. As described in Chapter 4,

Meshkati's Observation
Page 223

- BP conducted its own accident investigation of Deepwater Horizon, but once again kept its scope extremely narrow.(31) Professor Najmedin Meshkati of the University of Southern California, Los Angles—a member of the separate National Academy of Engineering committee investigating the oil spill—criticized BP's accident report for neglecting to "address human performance issues and organizational factors which, in any major accident investigation, constitute major contributing factors." He added that BP's investigation also ignored factors such as fatigue, long shifts, and the company's poor safety culture.(32)

The New York Times Editorial
December 19, 2011

A24 THE NEW YORK TIMES **EDITORIALS/LETTERS** MONDAY, DECEMBER 19, 2011

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Lessons of the Deepwater Horizon

Profits trumped safety and the gulf paid the price

The latest investigative report on the Deepwater Horizon disaster in the Gulf of Mexico, released Wednesday, is an important reminder of industry's past carelessness and a summons to vigilance in the future. It could not have been more timely, coming just as the Interior Department was concluding its first auction of new drilling leases in the gulf since the spill.

The report was prepared by the National Academy of Engineering and the National Research Council. It concluded — as had an earlier study by a presidential commission — that the explosion resulted from a series of poor decisions by BP and others, including a major miscalculation involving the ability of the well to withstand sudden increases in pressure. The study criticized both the industry and federal regulators for "misplaced trust" in the ability of blowout preventers to seal off wells in an emergency, and called for industry to redesign these devices to make them more reliable in the future.

More broadly, the report said that industry was far more focused on drilling and profits than it was on the need for preparedness and oversight. It said "the lack of a strong safety culture" was not unique to BP but was shared by its contractors and its regulators in the Interior Department's former Minerals Management Service.

Since the disaster, the Interior Department has put in place a whole new regime of safety regulations that companies must follow. The minerals service has been renamed and reorganized, and its inspection capabilities have been beefed up. Its new leaders have vowed that its mission will be to protect the public and the environment, not the industry it is charged with regulating.

Donald Winter, a former Navy secretary who directed the new study, said that because of these and other improvements, drilling in the gulf could safely proceed "at this point in time." But he warned, rightly, against overconfidence, especially now that drilling in the gulf has resumed and the Interior Department has started leasing new tracts that will lead to further exploration.

The search for new oil and gas reserves must be part of a balanced energy policy. But the enduring lesson of the Deepwater Horizon is that complacency can easily lead to disaster. The cost of the Deepwater Horizon blowout has been huge in both lost income and natural resource damage. The ultimate tally to BP and its partners could run as high as $40 billion, with civil penalties. The inescapable bottom line is that if industry wants to keep drilling, it needs to commit fully and completely to doing things differently. As do the regulators.

"The lack of strong safety culture"

BP Refinery Accident

March 23, 2005

U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD

INVESTIGATION REPORT

Final Draft for Board Vote

REFINERY EXPLOSION AND FIRE

(15 Killed, 180 Injured)

KEY ISSUES:

- SAFETY CULTURE
- REGULATORY OVERSIGHT
- PROCESS SAFETY METRICS
- HUMAN FACTORS

BP

TEXAS CITY, TEXAS

MARCH 23, 2005

REPORT NO. 2005-04-I-TX

MARCH 2007

BP Texas City Did Not Have a Positive Safety Culture

- Organizational causes were embedded in the refinery's history and culture
- Causes extended beyond the ISOM unit to actions of people at all levels of the corporation
- Multiple safety system deficiencies were found

San Bruno Gas Pipeline Accident

September 9, 2010

Figure 3. Aerial view of fire. - NTSB/PAR-11/01, P3

Paul Sakuma/Associated Press

- Pacific Gas and Electric Company (PG&E)
- Intrastate natural gas transmission pipeline
- September 9, 2010
- Residential area in San Bruno, California
- 47.6 million standard cubic feet of natural gas was released
- resulting in a fire that destroyed 38 homes and damaged 70.
- 8 people were killed, many were injured, and many more were evacuated from the area.

Mismanagement Blamed For Bay Area Gas Disaster

By MATTHEW L. WALD

WASHINGTON — The main cause of the natural gas pipeline rupture in San Bruno, Calif., that killed eight people and burned three dozen houses last September was 54 years of bad management by the Pacific Gas & Electric Company, and state and federal regulators who did not notice the problem, the National Transportation Safety Board said on Tuesday.

The board, by law, does not find blame, but only "probable cause." But when the five-member board finished reviewing a lengthy staff report on the explosion, it took the unusual step of voting to change the title. Instead of giving only the type of accident and the location, as is customary, it added the company's name.

"The city of San Bruno did not have this accident," said Robert L. Sumwalt, the board member who proposed the title change. "The city of San Bruno and her residents were victims of this accident."

The pipeline ruptured at a spot where utility workers installed bad pipe in 1956, skipping half the welds and either not inspecting the finished product or grossly misinterpreting the results, investigators said. But it was not a one-time lapse: the company failed to maintain records or assess risk, to understand its own computerized control centers or to learn from other recent accidents, the investigative agency's staff said on Tuesday.

After the rupture, it took the company an hour to shut off the gas because of poor planning and organization, according to the board. And months later, PG&E was tardy in supplying information about a previous leak from the same pipe, the board said.

A spokesman for PG&E, Brian Swanson, said the company was now focused on following the safety board's recommendations. "We've acknowledged our past operations and our past record-keeping procedures were not what they should have been," Mr. Swanson said.

The board issued an unusual number of recommendations, 38. One, to federal regulators, was that all pipelines be tested by pumping them full of water at high pressure. Existing rules exempt older pipelines, like the one in San Bruno.

The board said San Bruno was "an organizational accident."

On the day of the accident, Sept. 9, 2010, the fatal sequence began when workers at a computerized control center in Milpitas, Calif., were replacing a power system, but their work plan was poorly drawn and resulted in sensors erroneously reporting low pressure. That led to the automatic opening of valves, raising the pressure above what was intended. Even though the pressure did not reach the maximum the pipeline was supposed to hold, it failed because workers had skipped one set of welds when they installed the pipe in 1956, investigators said. The lack of welds should have been obvious in a visual inspection, they said.

The chairwoman of the board, Deborah A. P. Hersman, said that when she visited the site on the San Francisco peninsula, she found it "baffling" that a company in an earthquake-prone area could not figure out quickly that a pipeline had ruptured and close the appropriate valves. Some of the crucial work to close those valves was done by off-duty mechanics who "self-dispatched," the board staff found.

Ms. Hersman contrasted the gas utility's poor performance in the accident with television advertisements she saw while in California to visit the explosion site. In those ads, the company said it was installing "smart meters" at customers' homes that could tell instantly how much gas and electricity was being used, and communicate that information to the customers. But in a major transmission line, she said, "for a good half an hour or an hour, they can't even isolate where the rupture occurred." And months after the disaster, the company was still failing to provide timely information about problems, she said.

The safety board also had harsh words for both the California Public Utilities Commission, which it said had inappropriately trusted the company, and the United States Department of Transportation, which had failed to oversee the work of the state agency.

Newer pipelines must be tested by pumping them up with water, but the federal and state governments exempted older pipelines, including the San Bruno one. This pipe would have failed in a test had one been conducted, board investigators said.

The Safety Board is already investigating four other pipeline ruptures. The spate of accidents comes as gas production is increasing, and environmentalists are hoping that new supplies of gas will replace coal, to reduce air pollution. Meanwhile, the pipelines are getting older.

As part of a national effort to improve safety, the Department of Transportation on Aug. 25 asked for public comment on proposed new pipeline safety rules. Possible changes include redefining "high consequence areas," in which more frequent surveillance and inspection is required. Among others are whether pipeline operators should be required to install valves at shorter intervals; whether the valves must be capable of operation by remote control; and whether rules on corrosion control should be stricter. Some pipeline operators would have to reduce the maximum allowable pressure under the preliminary rules.

MANUEL BALCE CENETA/ASSOCIATED PRESS

Deborah Hersman, right, the safety board chairwoman, found it "baffling" that PG&E could not quickly figure out that a pipeline had ruptured.

PAUL SAKUMA/ASSOCIATED PRESS

Mismanagement Blamed for Bay Area Gas Disaster

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- The safety board also had harsh words for both the California Public Utilities Commission, which it said had inappropriately trusted the company, and the United States Department of Transportation, which had failed to oversee the work of the state agency.

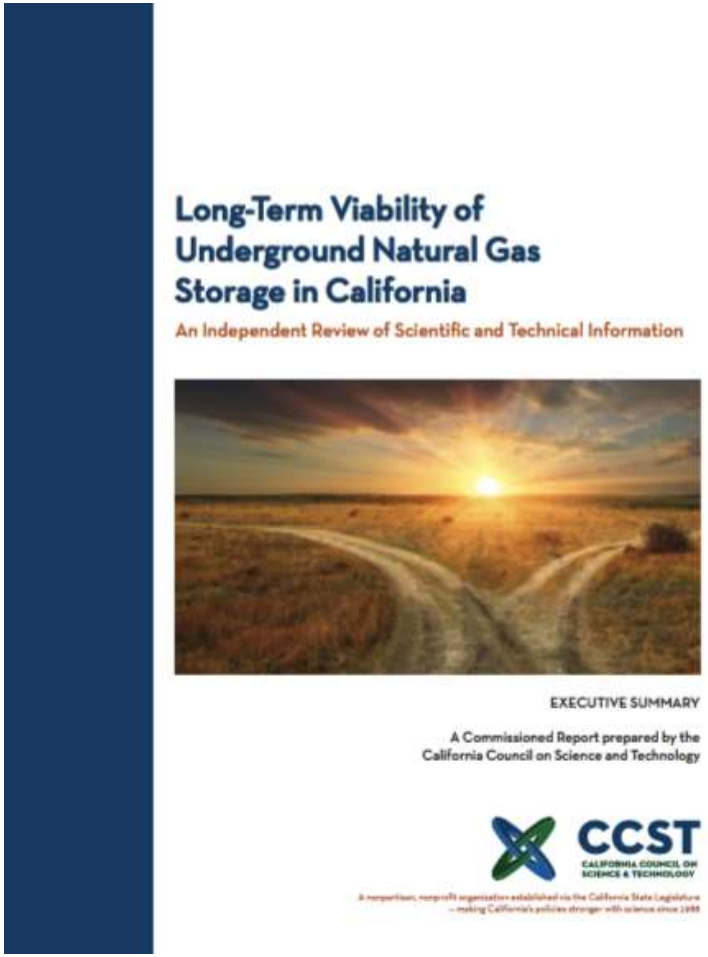
Aliso Canyon Underground Gas Storage Accident

October 23, 2015

And recently, closer to home (LA/USC)…
Aliso Canyon

October 23, 2015

CCST UGS Report (Jan 2018)



Long-Term Viability of Underground Natural Gas Storage in California

An Independent Review of Scientific and Technical Information

Summary Report

Jane C.S. Long, PhD, Independent Consultant
Steering Committee Co-Chair

Jens T. Birkholzer, PhD, Lawrence Berkeley National Laboratory
Steering Committee Co-Chair

Amber J. Mace, PhD, California Council on Science and Technology
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Sarah E. Brady, PhD, California Council on Science and Technology
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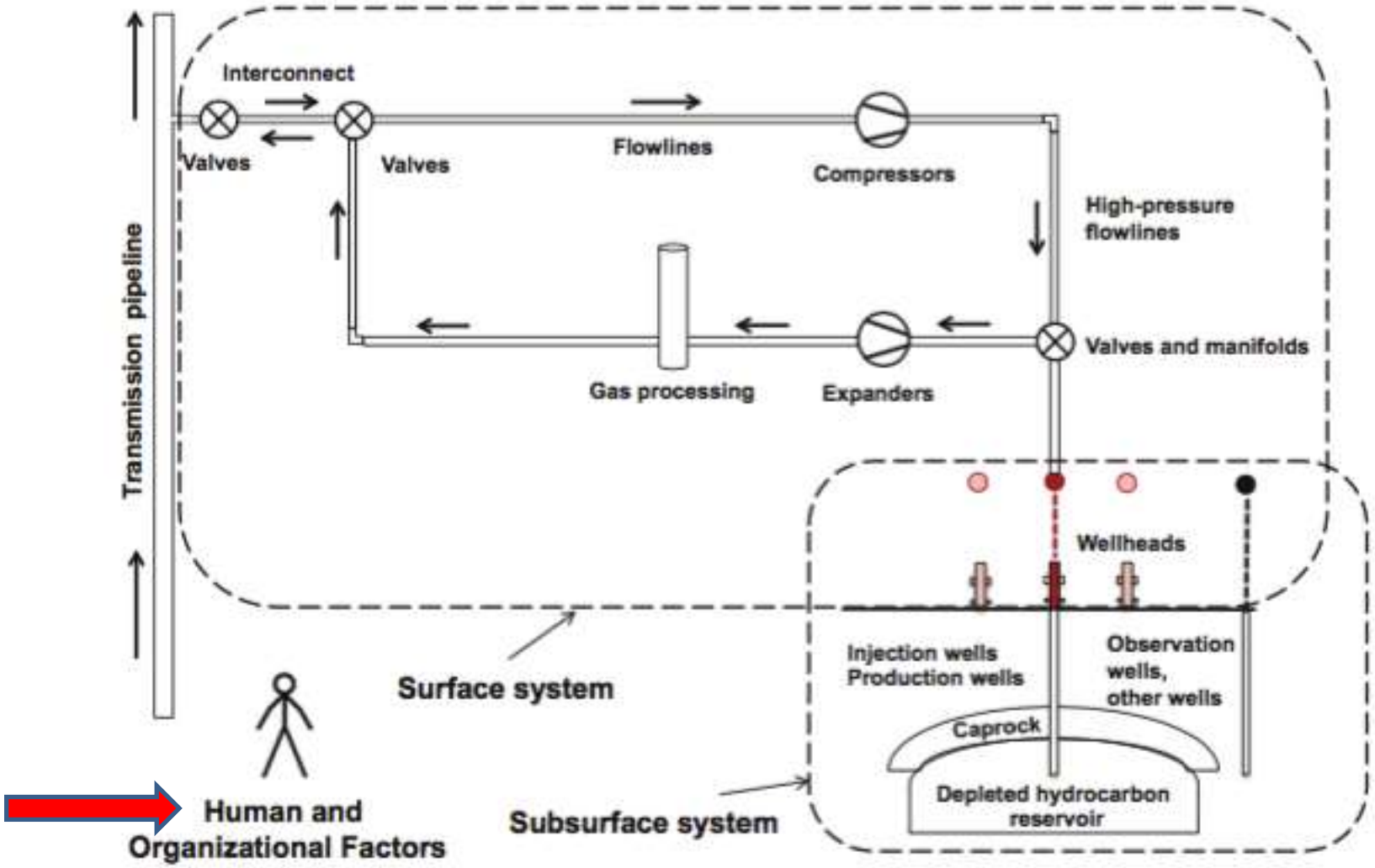


Figure 1.0-1. Simplified schematic of the main components of UGS facilities in California, showing examples of engineered surface components and the wells and geologic features comprising the subsurface system. Human and organizational factors play a critical role in control of both surface and subsurface systems.

The human figure depicted in Figure 1.0-1 represents the human and organizational factors (HOFs) of UGS. Human managers, engineers, and technicians employed by the operating company, along with contractors, provide one component of the human factor element controlling both the surface and subsurface parts of the UGS system. Another part of the human factor component comprises the general public and the local population. In addition, operational practices are inevitably influenced by long- and short-term organizational and cultural factors present in the UGS operating company. Section 1.2.6 and a side bar in Section 1.6 elaborate further on HOF's and safety culture. (p. 14)

Side Bar: Safety Culture

Page 342-435

Side bar: Safety Culture

NOTE: The following side bar was contributed by Professor Najmedin Meshkati, a member of the CCST Project's Steering Committee, who was also a member of the "Committee for Analysis of Causes of the Deepwater Horizon Explosion, Fire, and Oil Spill to Identify Measures to Prevent Similar Accidents to the Future," formed by the National Academy of Engineering/National Research Council. The following text is partially adopted from the published report of that same committee, entitled "Macondo Well Deepwater Horizon Blowout: Lessons for Improving Offshore Drilling Safety," (pp. 92-93 of Macondo Well-Deepwater Horizon Blowout: Lessons for Offshore Drilling Safety, National Research Council, 2012) and also updated and augmented by Professor Najmedin.

Although the emphasis in the text of this side bar is on the type of accidents similar to the Macondo Well blowout accident, the overall ideas concerning safety culture are broadly applicable, including to underground gas storage facilities.

The steps taken by the nuclear power and other safety-critical industries to improve system safety are reminiscent of the challenges presently confronting the offshore drilling industry. Although there are significant differences between the oil and gas industry and other industries (as discussed in this chapter), the safety framework and perspectives developed by those other industries can provide useful insights. According to the Swedish Radiation Safety Authority, an organization has good potential for safety when it has developed a safety culture that shows a willingness and an ability to understand risks and manage activities so that safety is taken into account (Oedewald et al., 2011). Other industries, regulatory agencies, trade associations, and professional associations have also addressed safety culture (for example, see Reason, 1998; U.S. NRC 2009; 2011; Nuclear Energy Institute, 2009; CCPS, 2005; IAEA, 1992).

The U.K. Health and Safety Executive defines safety culture as "the product of individual group values, attitudes and perceptions, competencies and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management." Creating safety culture means instilling attitudes and procedures in individuals and organizations ensuring that safety issues are treated as high priority, too. A facility fostering strong safety culture would encourage employees to cultivate a questioning attitude and a rigorous and prudent approach to all aspects of their jobs, and to set up necessary open communication between line workers and middle and upper management (Meshkati, 1999).

A commonly accepted and widely used/cited definition of safety culture was jointly developed through an unprecedented collaboration of the government regulator, United States Nuclear Regulatory Commission (U.S. NRC), and the industry's created self-regulatory body, the Institute of Nuclear Power Operations (INPO). According to this definition, safety culture is "the core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment" (INPO, Traits of a Healthy Nuclear Safety Culture, INPO 12-012 April 2013).

An effective and healthy safety culture embodies the following generic traits [The traits are adapted from the U.S. Nuclear Regulatory Commission Safety Culture Policy Statement (U.S. NRC, 2011)]:

- Leadership safety values and actions: Safety is treated as a complex and systemic phenomenon. It is also a genuine value that is reflected in the decision-making and daily activities of an organization in managing risks and preventing accidents.
- Personal accountability: All individuals take personal responsibility for safety and contribute to overall safety.
- Problem identification and resolution: Issues potentially affecting safety are readily identified, fully evaluated, and promptly addressed and corrected.
- Work processes: The process of planning and controlling work activities is implemented so that system safety is maintained. The most serious safety issues get the greatest attention.
- Continuous learning: Opportunities to learn about ways to ensure safety are sought out and implemented by organizations and personnel. Hazards, procedures, and job responsibilities are thoroughly understood. Safety culture strives to be flexible and adjustable so that personnel are able to identify and react appropriately to various indications of hazard. These processes and approaches are embedded in management systems and processes that are widely used within the organization.
- Environment for raising concerns: A safety-conscious work environment is maintained, where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment, or discrimination. They perceive their reporting as being meaningful to their organizations and thus avoid underreporting.
- Effective safety communication: Communications maintain a focus on safety. Knowledge and experience are shared across organizational boundaries, especially when different companies are involved in various phases of the same project. Knowledge and experience are also shared vertically within an organization.
- Respectful work environment: Trust and respect permeate the organization.
- Questioning attitude: Individuals avoid complacency and continuously challenge existing conditions and activities to identify discrepancies that might result in unsafe conditions. A subordinate does not hesitate to question a supervisor, and a contractor employee does not hesitate to question an employee of an operating company.

[It should be noted that the above definition and traits of healthy safety culture, which have been jointly developed by the U.S. NRC and INPO, have been adopted, almost exactly, by other federal regulatory and safety agencies, e.g., Bureau of Safety and Environmental Enforcement (U.S. BSEE, 2013).]

- Investigations of several large-scale accidents in recent years provide clear illustrations of the consequences of a deficient safety culture. A collision of two trains of the Washington Metropolitan Area Transit Authority (WMATA) Metrorail that occurred in June 2009 resulted in nine deaths and multiple passenger injuries. The National Transportation Safety Board (NTSB)

found that WMATA failed to implement many significant attributes of a sound safety program (NTSB 2010).

- The NTSB, which, by quoting Professor James Reason, has called it an "organizational accident," stated that "the accident did not result from the actions of an individual but from the 'accumulation of latent conditions within the maintenance, managerial and organizational spheres' making it an example of a 'quintessential organizational accident'" (NTSB, 2011; Reason, 1998).

- The rupture of the natural gas transmission pipeline that was owned and operated by the Pacific Gas and Electric Company (PG&E), in a residential area in San Bruno, California, on September 9, 2010, is another example of catastrophic "organizational accident" ("Mismanagement Blamed for Bay Area Gas Disaster," *New York Times*, August 30, 2011, by Matthew L. Wald), which has been attributed to the safety culture of the company and lax regulatory oversight, according to the NTSB (2011). PG&E estimated that 47.6 million standard cubic feet of natural gas was released; the released natural gas ignited, resulting in a fire that destroyed 38 homes and damaged 70. Eight people were killed, many were injured, and many more were evacuated from the area.

- Explosions and fires at the BP Texas City Refinery in March 2005 killed 15 people and injured 180 others. The U.S. Chemical Safety and Hazard Investigation Board concluded that the disaster was caused by organizational and safety deficiencies at all levels of the BP Corporation. The U.S. Chemical Safety and Hazard Investigation Board has identified "safety culture" as one of the four "key issues" which caused this accident, along with regulatory oversight, process safety metrics, and human factors (CSB, 2007).

- According to three major seminal reports that investigated the BP Deepwater Horizon (DWH) blowout, inadequate management systems and poor safety culture were major underlying causes of that blowout [Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling, Report to the President - National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling - January 2011 (2011); the National Research Council's Macondo Well-Deepwater Horizon Blowout: Lessons for Offshore Drilling Safety (2011); and the U.S. Chemical Safety Board (CSB) (June 2016).]

- The American Petroleum Institute (API) Recommended Practice 1173, Pipeline Safety Management System Requirements (First Edition, June 2014, Draft Version 11.2; https://www.pipelinelaw.com/wp-content/uploads/sites/19/2014/09/API-RP-1173.pdf) entire section 10.6 is about "Evaluation of Safety Culture." It recommends that:

- "The pipeline operator shall establish methods to evaluate the safety culture of its organization. Operators shall assess the health of their safety culture using methods that assess employee perception of the safety culture. Methods to assess the perception of the culture include but are not limited to questionnaires, interviews, and focus groups. Policies, operating procedures, continuous vigilance and mindfulness, reporting processes, sharing of lessons learned and employee and contractor engagement support an operator's safety culture. Observations and audits of how each of these are being applied in the daily conduct of operations provide indications of the health of an organization's safety culture, including conformance with policies, adherence to operating procedures, practicing vigilance and mindfulness, utilizing reporting processes, integrating lessons learned and engagement of employees and contractors. Failure in application of these provides an indication of potential deterioration of the safety culture. Management shall review the results and findings of perception assessments, observations and audits and define how to improve application of the supporting attributes." (p. 17)

The U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration's (PHMSA) "fully supports the implementation of RP 1173 and plans to promote vigorous conformance to this voluntary standard." Although PHMSA has not yet issued an official safety culture policy statement, it has adopted the Safety Management Systems (SMS) concept and contends that it has been "actively advancing implementation of SMS and a *strong safety culture* within the pipeline and hazardous materials sectors is the next step in continuous safety improvement for America's hazardous materials transportation system." (emphasis added, PHMSA Administrator the Honorable Marie Therese Dominguez's written statement before the U.S. House of Representatives, February 25, 2016).

The American Gas Association (AGA), which is a trade organization representing over 200 natural gas supply companies and others, has also echoed and endorsed the importance of safety culture and its AGA's Safety Culture Statement states, "The AGA and its member companies are committed to promoting positive safety cultures among their employees throughout the natural gas distribution industry" (AGA, 2011).

Most recently, on May 18, 2017, the State of California's Department of Industrial Relations' (DIR) Occupational Safety and Health Standards Board has announced that it has approved adding safety culture as one of new elements to its revamped/updated regulations on refinery safety. [In this regulation, which has been applauded by the industry's trade association, the Western States Petroleum Association (WSPA), and which became effective on October 1, 2017, the "Process Safety Culture," is defined as: "A combination of group values and behaviors that reflects whether there is a collective commitment by leaders and individuals to emphasize process safety over competing goals, in order to ensure protection of people and the environment."] This order is enforced by CalOSHA's Process Safety Management (PSM) Unit, adding section 5189.1 to Title 8 of the California Code of Regulations. This element outlined in the regulation requires refinery employers to: "Understand the attitudes, beliefs, perceptions and values that employees share in relation to safety and evaluate responses to reports of hazards by implementing and maintaining an effective Process Safety Culture Assessment program" (CalOSHA, 2017b).

Boston/Lawrence Columbia Gas Pipeline Explosion and Fire

September 13, 2018

The Boston Globe

FRIDAY, SEPTEMBER 14, 2018

Explosions, flames, and fear

A house in Lawrence was destroyed by one of the explosions that rocked three communities in the Merrimack Valley on Thursday.

Suspicions about natural gas, pipes
Columbia Gas, which supplies residents of the three communities, had been upgrading this week. A6

People covered their faces on Bowdoin Street in Lawrence (above). In North Andover, firefighters grappled with a blaze on Herrick Road.

Gas turned off after destruction in 3 communities; one person killed

By Brian MacQuarrie and Joshua Miller
GLOBE STAFF

LAWRENCE — More than 40 gas explosions and fires rocked Lawrence, North Andover, and Andover in a staccato burst of flame and fear late Thursday afternoon, damaging dozens of buildings and prompting mass evacuations from homes served by Columbia Gas.

State and local emergency workers descended quickly on the three Merrimack Valley communities, battling the fires, tending to the injured, and working frantically to pinpoint the cause of the explosions.

A Lawrence man died, and a local hospital treated at least 12 others injured in the fires, officials said. Leomel Rondon, 18, had been sitting inside a car when an explosion in Lawrence caused a chimney to fall on the vehicle, according to the Essex district attorney's office.

A spokeswoman for the state fire marshal's office said investigators are focusing on overpressurization of a gas main owned by Columbia Gas, which serves about 50,000 customers in and

EXPLOSIONS, Page A8

For residents, a day of sudden, shocking chaos

By Dugan Arnett, Jerome Campbell, and Danny McDonald
GLOBE STAFF

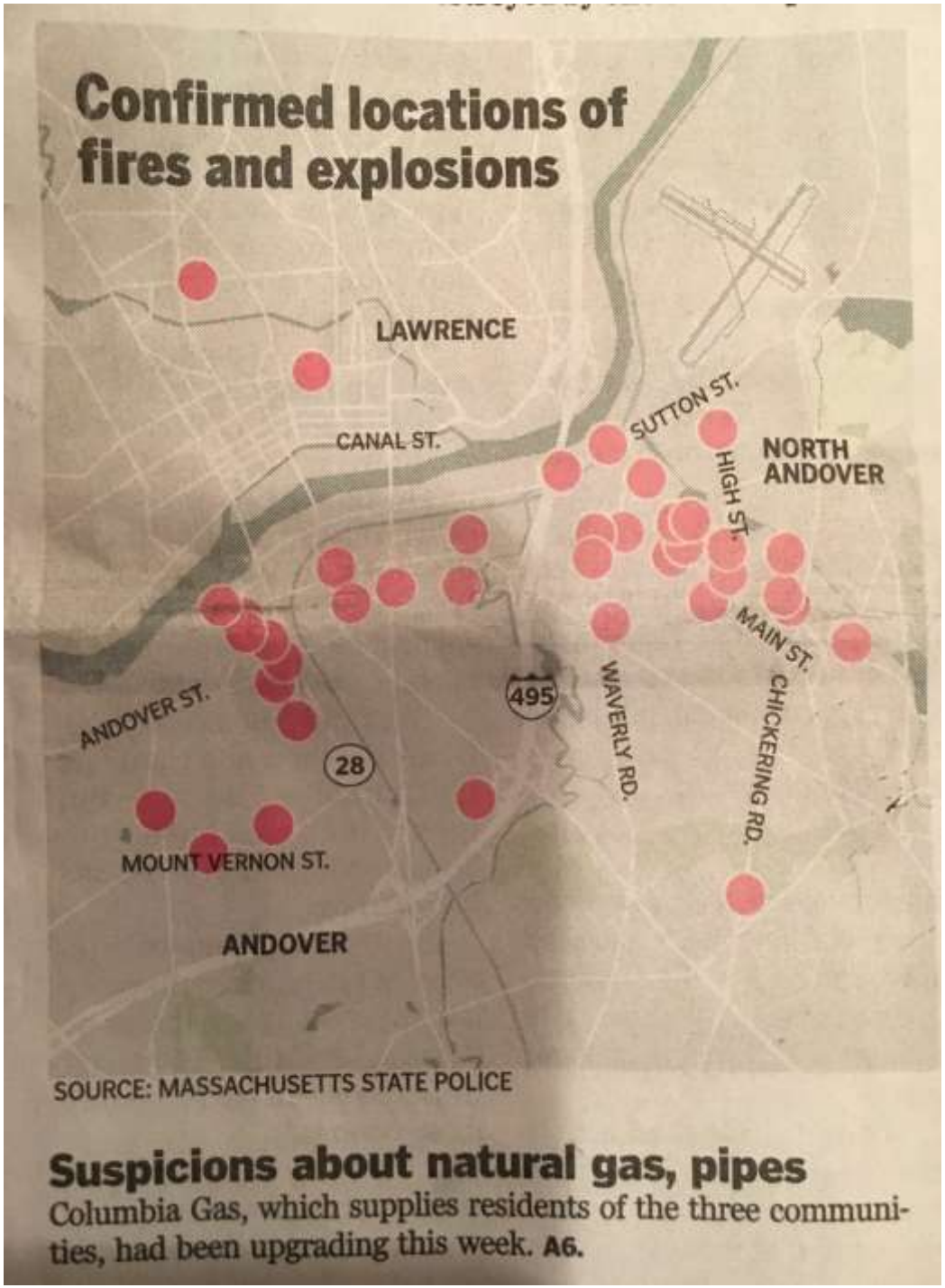
LAWRENCE — Matthew Van Dyke was letting his dogs out late Thursday afternoon when he heard a loud boom.

Then he saw at least four people, whom he believed to be teenagers, rush out of a single-family home on Chickering Road. One of them was limping.

In just seconds, the home collapsed, after a disastrous natural gas explosion caused dozens of fires across Lawrence, Andover, and North Andover. As many as 70 properties were damaged or destroyed as fires rocked the Merrimack Valley communities.

The sides of the Chickering Road

RESIDENTS, Page A7



Suspicions about natural gas, pipes

Columbia Gas, which supplies residents of the three communities, had been upgrading this week. **A6.**


BOSTON
Herald
BOSTONHERALD.COM
STREETS
OF FIRE
TRAGEDY, CHAOS AS 70 GAS-RELATED
EXPLOSIONS, BLAZES ROCK LAWRENCE,
SURROUNDING COMMUNITIES
NECA
LOCAL 103
IBEW
POWERING FENWAY PARK
PROUD PARTNERS OF THE BOSTON RED SOX

The Honorable Robert Sumwalt, NTSB Chairman, Press Briefing

Sunday Sept 16, 2018

- We found evidence from an evidentiary dig this morning that pressure sensors were attached to a gas line that was being placed out of service and being capped off on Thursday.
- Certainly the investigation will answer 2 questions. What affect if any did this have on the over-pressure situation? And secondly, why was this sensor connected to a gas line that was being placed out of service?

Mr. Sumwalt's remarks…

- In the coming days, we will interview the construction foreman in charge of the job at South Union and Salem. We will interview the Columbia Gas Inspector who oversees this construction crew. We will interview the Columbia Gas pipeline safety, excuse me, the Columbia Gas Pipeline Safety Supervisor. And we will interview the 4 people from the gas control center that I mentioned yesterday that is in Columbus, Ohio.

Mr. Sumwalt's remarks

- When we talk about construction, are we talking about Columbia Gas working on their own lines, the answer to that is yes. They were using contractors to do that work, but it was Columbia Gas construction and as you probably know, they're in the process of replacing old cast iron pipe with new plastic pipe. So yes, the construction was done at the request of Columbia Gas.